What is claimed is:

1. An apparatus comprising:

a band-gap light guidance region having a hollow void within which light is guided by a band-gap effect;

a microstructure disposed adjacent to the hollow void for enhancing light guidance; and

a plurality of active gain material disposed in an interface area between the hollow void and the microstructure for providing active gain to the light guidance.

2. The apparatus of claim 1, wherein the microstructure comprises a photonic crystal waveguide and the interface area comprises a signal and pump overlap portion doped with active materials that spatially overlap guided modes of the waveguide, wherein the photonic crystal waveguide comprising:

a dielectric confinement region surrounding a waveguide axis, the confinement region comprising a photonic crystal having at least one photonic band-gap, during operation the confinement region guides electro-magnetic (EM) radiation in a first range of frequencies to propagate along the waveguide axis as a first guided mode for propagating pump energy along the waveguide axis; and

the plurality of active gain material disposed in the signal and pump overlap portion of the dielectric confinement absorbs the pump energy and stores the pump energy as a potential energy source for stimulation by a signal energy for emitting EM energy in a second guided mode at a second frequency in a second range of frequencies for spatially overlapping with the first guided mode such that the surface defined by an interface between the at least one photonic band-gap region and the hollow void that supports at least one surface mode propagating at that interface overlaps the signal and pump overlap and a state associated with the hollow void.

3. The apparatus of claim 2, further comprising an excitation source, applied to the interface area having a radius in a range greater than the radius of the hollow void by a factor of 1.0-3.0, for causing the interface area to emit electromagnetic radiation, wherein

the excitation source is configured to produce optical gain for the second guided mode at the second frequency.

4. The apparatus of claim 1, wherein the microstructure has a plurality of apertures to provide a void-filling fraction within a range of about 0.4 to 1.0.

5. The apparatus of claim 4, wherein the microstructure comprises an active photonic crystal band-gap fiber for providing optical gain for at least one optical mode that spectrally overlaps at least a portion of at least one photonic band-gap, the photonic crystal band-gap fiber having a pitch and pores having a volume fraction in a range about 44% to 98% of the photonic band-gap crystal and further having:

the hollow void providing a defect having a boundary that encloses a plane cross section and a length dimension perpendicular to the plane cross section, the defect boundary being characterized by a numerical value; wherein,

the numerical value is selected so that the wavelength of the localized mode produced by the defect propagates in the wavelength range of the photonic band-gap, and,

the ratio of the numerical value of said defect to the pitch is selected to interact with the excitation of surface modes within the photonic band-gap.

6. The apparatus of claim 1, wherein the microstructure comprises an active periodic two dimensional dielectric structure of a first periodicity having a plane of periodicity, comprising an active element and configured to produce a photonic band-gap having a first band-gap region; and

the active periodic two dimensional dielectric structure optically pumped by an excitation source to provide optical gain at the wavelength of the first band-gap region in a direction perpendicular to the plane of periodicity.

7. The apparatus of claim 6, further comprising: a second periodic structure of a second periodicity adjacent in the plane to the active periodic structure for confinement of optical energy by a second band-gap.

8. The apparatus of claim 7, wherein the hollow void provides a defect within the active periodic structure to create at least one photonic defect state within the first band-gap

region, such that amplification is produced at a frequency corresponding to the defect state.

9. The apparatus of claim 8, wherein the active element belongs to a group including an active gas, a rare earth element or a transitional metal element for disposing in a signal and pump overlap portion of the first periodic structure.

10. The apparatus of claim 9, wherein a surface defined by a signal and pump overlap portion of the periodic structure is disposed within the optical field of at least one photonic defect state and the defect supports at least one surface mode that overlaps at least one active element in the signal and pump overlap portion of the structure.

11. The apparatus of claim 1, wherein the microstructure comprises a Bragg photonic band-gap fiber having alternating layers of refractive index for defining a band-gap region.

12. The apparatus of claim 9, wherein the active periodic structure having a first void-filling fraction, and the second periodic structure having a second void-filling fraction, the second periodic structure being positioned adjacent to the active periodic structure.

13. The apparatus of claim 12, wherein the first void-filling fraction is smaller than the second void-filling fraction for confinement of the optical pump radiation using total internal reflection.

14. The apparatus of claim 12, wherein the first and second periodic structures are dielectric structures each having a periodic array of channels having the same first and second void-filling fractions configured to form a single band-gap that contains both a signal wavelength and a pump wavelength such that a signal mode and a pump mode are guided within the hollow void.

15. The apparatus of claim 12, wherein the first and second periodic structures are dielectric structures each having a periodic array of channels having different first and second void-filling fractions.

16. The apparatus of claim 1, wherein the interface area forms a portion of the microstructure such that the microstructure area including the interface area is about 10-300% greater than the interface area.

17. The apparatus of claim 10, wherein the active periodic structure having a first pitch (Λ) between band-gap-lattice apertures and a ratio of defect dimension (R_d) to pitch in a range from about 1.12 to 1.20 for configuring the band-gap region to provide the overlap for the surface mode and the core mode with the optical gain region and suppressing the surface mode at the signal wavelength.

18. The apparatus of claim 10, wherein the active periodic structure having a first pitch (Λ) between band-gap-lattice apertures having a dimension r_{cl}, a defect having a dimension R_d providing single mode and including a gas, the active periodic structure having a fractional volume of voids not less than 40%, the ratio of defect dimension to pitch has a range from about 1.12 to 1.20 for configuring the band-gap region to provide the overlap for the surface mode and the core mode with the optical gain region and suppressing the surface mode at the signal wavelength.

19. A fiber laser/amplifier comprising:

an active source having a pump light for providing an output power;

a double-clad optically active photonic band-gap fiber (PBGF) having a first end for receiving the pump light and a second end for outputting a laser signal, the double-clad optically active PBGF including

a defect core for supporting close to a single-mode transmission of the laser signal, the core having a cross-sectional core area;

an inner cladding disposed adjacent to the core having a first band-gap;

a plurality of optically excitable dopants having a transition requiring a high level of inversion at a desired signal wavelength of the laser signal disposed in an interface portion of the inner cladding adjacent to the defect core, the interface portion configured sufficiently small to match a laser mode field geometry of the pump light to allow the inner cladding to optically deliver the pump light to the core and the plurality of optically excitable dopants at a high pump power density and to allow a sufficiently large

overlap between dopants in the inner cladding interface portion and core modes of the defect core and the pump light, such that the high pump power density and the large overlap between dopants and the pump light provide the required level of inversion for lasing with a low power threshold and high efficiency; and

an outer cladding disposed adjacent in the plane to the inner cladding having a second band-gap with a second void-filling fraction different than the first void-filling fraction of the inner cladding for confining the pump light.

20. The apparatus of claim 19, wherein the fiber laser/amplifier comprises a narrow-linewidth amplifier for reducing SBS effects.

21. The apparatus of claim 19, further comprising a pair of feedback reflectors for the fiber laser/amplifier to lase as a laser.